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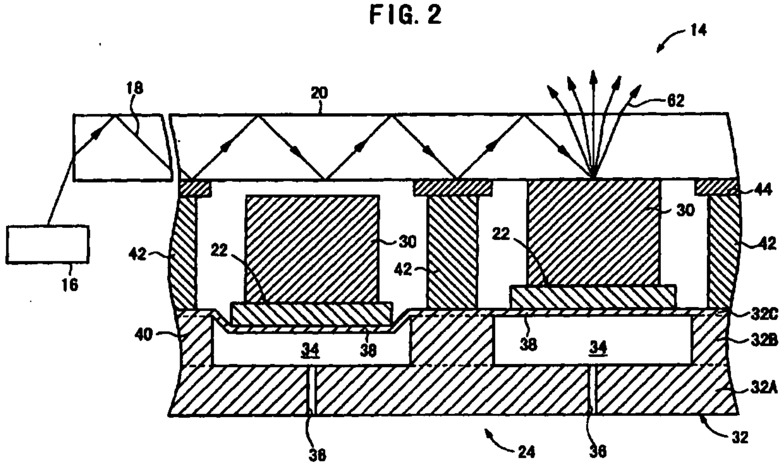
(54) Method and apparatus for driving a display device

(57) A display driving device drives a display which includes a plurality of actuators which control light emitted from specified parts of an optical wave guide plate. A first drive circuit controls the row electrodes, while a second drive circuit controls the column electrodes by outputting a data signal. The data signal includes a light emitting signal and a light extinguishing signal for each dot in the display, based on an input image signal. The column electrode drive circuit controls gradation only by a temporal modulation method. A signal processing circuit, which controls the first and second drive circuits, also controls brightness correction data. Brightness correction data are determined upon manufacture of the display and can be modified during the life of the display to correct for brightness deterioration.

FIG. 2



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Description

FIELD OF THE INVENTION

[0001] The present invention relates to display devices having significant screen brightness which consume a small amount of electric power, and in particular, to a display driving device which controls a variation of contact/separation directions of an actuator with respect to an optical wave guide plate in response to an input image signal input.

BACKGROUND OF THE INVENTION

[0002] Cathode ray tubes (CRT), liquid crystal devices and plasma display devices are known in the art. Cathode ray tubes are known as normal television receiving devices and monitor devices for computers. Although the screens are bright, they consume much electric power, and the overall depth of the display device relative to the size of the screen is great. In addition there are other problems such as diminished resolution in the peripheral portions of the display image, distorted images and graphics, lack of memory feature and an inability to achieve large scale displays. The reason for this is that the light emission point (beam spot) is broadened where electron beams reach the fluorescent face of the CRT diagonally because the electron beam is significantly deflected when fired from the electron gun that images are displayed obliquely. In addition, there are limits to maintaining vacuum in the large spaces of CRT's.

[0003] While liquid crystal displays have certain advantages such as being reduced in size and consuming little power, the brightness of the screen is inferior and the screen viewing angle is narrow. In addition, they have an additional disadvantage in that the configuration of the drive circuits has become very complex due to the fact that gradation expression (gray scale) is accomplished by changes in the voltage level. For example, when a digital data line is used, the drive circuit is configured to have a latch circuit which holds component RGB data (each 8 bits) for a specified period of time, a voltage selector, a multiplexer which switches the voltage level in response to the gradation number, and an output circuit for adding the data output from this multiplexer to a digital data line. In this case, if the gradation number increases, there is a need for the multiplexer to act to switch many levels, thus making the configuration more complex.

[0004] When an analog data line is used, the drive circuits are configured to have a shift register for aligning component RGB data (each 8 bits) successively input in a horizontal direction, a latch circuit which holds parallel data from the shift register a designated period of time, a level shifter which takes the voltage level adjustment, a digital to analog (D/A) converter which converts the data output from the level shifter to an analog signal, and an output circuit for adding the signal output from this D/A analog converter to an analog data stream. In this case, while a designated voltage is obtained in response to gradation by using an operating amplifier in the D/A converter, the use of an operating amplifier which outputs highly precise voltages becomes necessary as the range of gradation expand. This has the disadvantage that construction is more complex and more expensive.

[0005] Plasma displays are similar to liquid crystal display devices in that the display does not take up much space. In addition, since the plasma display is a flat surface, it has the advantage of being easy to view. In particular, with an alternating type plasma display, there is the added advantage that there is no need to have a refresh memory due to the cell memory function. However, there is a need to alternately switch the polarity of the voltage and have a continuous discharge in order to maintain the memory function in cells. Because of that, a first pulse generator that generates a sustained pulse in the X direction and a second pulse generator that generates a sustained pulse in the Y direction must be provided in the drive circuits. Thus there is a problem that the configuration of the drive circuits is more complex.

[0006] A recently developed display device, shown in Fig. 66, includes an actuator 1000. Actuator 1000 is configured with an actuator unit 1008 that has a piezoelectric/ electrostriction layer 1002 sandwiched between an upper electrode 1004 and a lower electrode 1006 formed respectively on the upper and lower surfaces of piezoelectric/ electrostriction layer 1002. A substrate 1014 includes a vibrator 1010 and a securing portion 1012. Vibrator 1010 is disposed on a lower part of actuator unit 1008. Lower electrode 1006 contacts vibrator 1010 such that actuator unit 1008 is supported by vibrator 1010.

[0007] Substrate 1014 is composed of ceramic. A concave portion 1016 is formed in substrate 1014 and of a size so that vibrator 1010 is relatively thin. A displacement transfer portion 1020 makes the area of contact with optical wave guide plate 1018 a designated size. Displacement transfer portion 1020 is connected to upper electrode 1004 of actuator unit 1008, and in the example in Fig. 66, displacement transfer portion 1020 is located close to optical wave guide plate 1018 when actuator 1000 is in a normal state (unmoved) and is disposed so that it contacts optical wave guide plate 1018 at a distance equal to or less than the wave length of light when in a state of excitation.

[0008] Then, for example, light 1022 is introduced from the end of optical wave guide plate 1018. In this case, all of light 1022 is totally reflect in the interior without passing the front face and back face of optical wave guide plate 1018 due to the index of refraction of optical wave guide plate 1018. In this state, a voltage signal corresponding to an image signal is selectively applied to actuator 1000 via upper electrode 1004 and lower electrode 1006. By performing the dis-

placement due to normal and excited states of actuator 1000, the contact and separation of optical wave guide plate 1018 with displacement transfer portion 1020 is controlled. By virtue of this, the scattered light (leakage light) 1024 of optical wave guide plate 1018 is controlled and an image corresponding to the image signal is displayed on optical wave guide plate 1018.

[0009] This display device has the following advantages: (1) it reduces power consumption, (2) it increases screen brightness, and (3) when using a color screen, there is no need to increase the number of pixels as compared to a black and white screen.

[0010] The peripheral circuits of the display device as described above, shown in Fig. 67, are configured to have a display 1030 which has multiple arranged pixels, a vertical shift circuit 1034 which deduces the number of rows necessary for vertical selection line 1032 (which are common to the pixels comprising one column), and a horizontal shift circuit 1038 which deduces the number of columns necessary for signal line 1036, which are common to the pixels comprising one column. Because of that, the display information (output voltage) output for the pixel groups of a selected row from horizontal shift circuit 1038 is also applied to the pixel groups related to non-selected rows, thus driving unnecessary pixels. Thus, unnecessary power consumption occurs, which is a disadvantage in reducing the consumption of electric power.

[0011] In addition, in endeavoring to improve brightness and contrast with such things as memory effect while increasing the row selection number during the vertical scanning interval, there is a need to supply high voltage to the vertical shift circuit. Moreover, there is a necessity to supply at least three levels of voltage, thus making customization of an IC for the vertical shift circuit more difficult. Reducing the size of the IC's and making them have many outputs becomes difficult, and making displays thinner is hindered by the packaging space of driver IC.

SUMMARY OF THE INVENTION

[0012] Briefly stated, a display driving device drives a display which includes an optical wave guide plate and a drive section disposed opposite one face of the optical wave guide plate. The display includes a plurality of actuators which control light emitted from specified parts of the optical wave guide plate. The display driving device includes a first drive circuit which applies an offset potential (bias potential) to all actuators, a second drive circuit which outputs a data signal, and a signal processing circuit. The data signal includes a light emitting signal and a light extinguishing signal for each dot in the display, based on an input image signal. The signal processing circuit controls the row electrode drive circuit and the column electrode drive circuit. The column electrode drive circuit controls gradation by a temporal modulation method. Pixel brightness is controlled by the signal processing circuit to decrease the brightness variance between dots caused by the manufacturing process.

[0013] The row electrode drive circuit, the column electrode drive circuit, and the signal processing circuit are packaged in the periphery of the display. The row electrode drive circuit is configured so that it supplies offset electrical potential (bias potential) to the row electrodes of all actuators by virtue of a common wire, where each wire and one level of voltage for offset is supplied through the power source. The column electrode drive circuit includes a number of driver outputs corresponding to the total number of dots, and is configured so that it outputs a data signal to each data wire of the display in parallel so that it supplies respective data signals to all dots. Two levels of voltage for data are supplied to each driver output by the power supply.

[0014] In a feature of the invention, the signal processing circuit includes a linear correction mechanism for making display properties linear with respect to the gradation level. This facilitates an accurate display and improves contrast, resulting in a sharper image since the display properties change linearly in each dot in response to variations in the gradation level. In current color television formats, gamma correction on the transmitted image (transmission) side is performed to reduce the cost of receivers. This correction becomes unnecessary with a display which uses an optical wave guide as in this invention since the gamma correction is always focused on Braun tubes. Therefore, degradation of resolution of portions of an image with high color saturation does not occur even when displaying a television signal which has been gamma corrected. It is thus possible to evoke the appearance of a crisp display image, because the display properties with respect to the gradation level in the transmission can be corrected linearly.

[0015] In a feature of the invention, a light adjustment control mechanism switches the power of a light source in at least two stages at a desired timing in one frame when the display interval of one image is one frame. When applied to a display which uses linear subfields, the brightness level of each linear subfield varies with adjustment of the light source. For example, when the switches of the power of the light source are set to 100% and 25%, linear sub fields which have brightness level 4 and brightness level 1 are defined to correspond to power switch timing of the light source, and when 64 gradations are expressed just by brightness level 1, they can be expanded to 256 gradations. In addition, since it does not use all the power in one frame, consumption of electric power can be reduced.

[0016] In a feature of the invention, a preliminary interval separates all dots in one frame with respect to the optical wave guide plate when the display interval of one image is one frame. By virtue of this, there is no degradation of the responsiveness of the separation of the actuator because an image is displayed from the point that all dots are OFF by

designating a preliminary interval before the actual image display interval. The preliminary interval is preferably formed coincidental to variations in the output level of the first drive circuit. The yield and reliability of the display is improved.

[0017] According to an embodiment of the invention, a display driving device for a display includes an optical wave guide plate which introduces light to the display; a drive section disposed opposite one face of the optical wave guide plate, the drive section including a plurality of actuators arranged corresponding to a plurality of pixels which in turn correspond to a plurality of dots, the drive section controlling a displacement of the plurality of actuators in contacting and separating directions with respect to the optical wave guide plate, the displacement corresponding to attributes of an input image signal, thereby causing an image to be displayed on the optical wave guide plate corresponding to the image signal by controlling a leakage light from specified parts of the optical wave guide plate; a first drive circuit which applies an offset potential to all of the actuators; a second drive circuit which outputs a data signal for each dot, the data signal being based on the image signal, the data signal comprising one of a light emitting signal and a light extinguishing signal; and a signal processing circuit which controls the first and second drive circuits wherein one dot is configured by one or more actuators and one pixel is configured by one or more dots, wherein the signal processing circuit controls at least the second drive circuit which in turn controls gradation by at least a temporal modulation method.

[0018] According to an embodiment of the invention, a display driving device for a display includes an optical wave guide plate which introduces light to the display; a drive section disposed opposite one face of the optical wave guide plate, the drive section including a plurality of actuators arranged corresponding to a plurality of pixels which in turn correspond to a plurality of dots, the drive section controlling a displacement of the plurality of actuators in contacting/separating directions with respect to the optical wave guide plate, the displacement corresponding to attributes of an input image signal, thereby causing an image to be displayed on the optical wave guide plate corresponding to the image signal by controlling a leakage light from specified parts of the optical wave guide plate; a first drive circuit which alternately selects pixels for odd numbered rows and even numbered rows; a second drive circuit which outputs a data signal for each dot, the data signal being based on image signal, the data signal including one of a light emitting signal and a light extinguishing signal; and a signal processing circuit which controls the first and second drive circuits, wherein one dot is configured by one or more actuators and one pixel is configured by one or more dots, and wherein the signal processing circuit controls at least the second drive circuit which in turn controls gradation by at least a temporal modulation method.

[0019] According to an embodiment of the invention, a method of driving displays includes introducing light in an optical wave guide plate; providing a plurality of actuators arranged corresponding to a plurality of pixels which in turn correspond to a plurality of dots; providing a drive section disposed opposite one face of the optical wave guide plate which controls a displacement of the actuators in contacting/separating directions with respect to the optical wave guide plate corresponding to attributes of an input image signal, thereby causing an image to be displayed on the optical wave guide plate corresponding to the input image signal by controlling leakage light of specified parts of the optical wave guide plate; configuring each dot by at least one actuator; configuring each pixel by at least one dot; applying an offset potential to the plurality of dots; outputting a data signal comprising a light emitting signal and a light extinguishing signal for each dot based on the input image signal; and controlling gradation by at least a temporal modulation method.

[0020] According to an embodiment of the invention, a method of driving displays includes the steps of introducing light in an optical wave guide plate; providing a plurality of actuators arranged corresponding to a plurality of pixels which in turn correspond to a plurality of dots; providing a drive section disposed opposite one face of the optical wave guide plate which controls a displacement of the actuators in contacting/separating directions with respect to the optical wave guide plate corresponding to attributes of an input image signal, thereby causing an image to be displayed on the optical wave guide plate corresponding to the input image signal by controlling leakage light of specified parts of the optical wave guide plate; configuring each dot by at least one actuator; configuring each pixel by at least one dot; alternately selecting pixels of odd number rows and even number rows; outputting display information to pixels of the selected rows for each dot based on the input image signal, wherein the display information includes a light emitting signal and a light extinguishing signal; and controlling gradation by at least a temporal modulation method.

[0021] According to an embodiment of the invention, a display driving device for a display includes an optical wave guide plate which introduces light to the display; a drive section disposed opposite one face of the optical wave guide plate, the drive section including a plurality of actuators arranged corresponding to a plurality of pixels which in turn correspond to a plurality of dots, the drive section controlling a displacement of the plurality of actuators in contacting/separating directions with respect to the optical wave guide plate, the displacement corresponding to attributes of an input image signal, thereby causing an image to be displayed on the optical wave guide plate corresponding to the image signal by controlling a leakage light from specified parts of the optical wave guide plate; a first drive circuit which selects dots of designated rows for the plurality of pixels; a second drive circuit which outputs a data signal for each dot, the data signal being based on the input image signal, the data signal including one of a light emitting signal and a light extinguishing signal; and a signal processing circuit which controls the first and second drive circuits, wherein one dot is configured by one or more actuators and one pixel is configured by one or more dots, and wherein the signal processing circuit controls the first and second drive circuits which in turn control gradation by at least a temporal modulation

method.

[0022] According to an embodiment of the invention a method of driving displays includes the steps of introducing light in an optical wave guide plate; providing a plurality of actuators arranged corresponding to a plurality of pixels which in turn correspond to a plurality of dots; providing a drive section disposed opposite one face of the optical wave guide plate which controls a displacement of the actuators in contacting/separating directions with respect to the optical wave guide plate corresponding to attributes of an input image signal, thereby causing an image to be displayed on the optical wave guide plate corresponding to the input image signal by controlling leakage light of specified parts of the optical wave guide plate; configuring each dot by at least one actuator; configuring each pixel by at least one dot; selecting, in turn, dots of all pixels in designated rows; outputting a data signal comprising a light emitting signal and a light extinguishing signal for each dot based on the input image signal; and controlling gradation by at least a temporal modulation method.

[0023] According to an embodiment of the invention, a display driving device for a display includes an optical wave guide plate which introduces light to the display; a drive section disposed opposite one face of the optical wave guide plate, the drive section including a plurality of actuators arranged corresponding to a plurality of pixels which in turn correspond to a plurality of dots, the drive section controlling a displacement of the plurality of actuators in contacting and separating directions with respect to the optical wave guide plate, the displacement corresponding to attributes of an input image signal, thereby causing an image to be displayed on the optical wave guide plate corresponding to the image signal by controlling a leakage light from specified parts of the optical wave guide plate; a first drive circuit which applies an offset potential to all of the actuators; a second drive circuit which outputs a data signal for each dot, the data signal being based on the image signal, the data signal comprising one of a light emitting signal and a light extinguishing signal; a signal processing circuit which controls the first and second drive circuits wherein one dot is configured by one or more actuators and one pixel is configured by one or more dots; wherein the signal processing circuit includes means for controlling gradation; and wherein the signal processing means includes correction means for correcting brightness to compensate for brightness variations between each of the dots.

[0024] According to an embodiment of the invention, a method of driving displays includes the steps of introducing light in an optical wave guide plate; providing a plurality of actuators arranged corresponding to a plurality of pixels which in turn correspond to a plurality of dots; providing a drive section disposed opposite one face of the optical wave guide plate which controls a displacement of the actuators in contacting/separating directions with respect to the optical wave guide plate corresponding to attributes of an input image signal, thereby causing an image to be displayed on the optical wave guide plate corresponding to the input image signal by controlling leakage light of specified parts of the optical wave guide plate; configuring each dot by at least one actuator; configuring each pixel by at least one dot; applying an offset potential to the plurality of dots; outputting a data signal comprising a light emitting signal and a light extinguishing signal for each dot based on the input image signal; controlling gradation; and performing brightness correction processing to correct brightness variations between each of the dots.

[0025] According to an embodiment of the invention, a display driving device for a display includes an optical wave guide plate which introduces light to the display; a drive section disposed opposite one face of the optical wave guide plate, the drive section including a plurality of actuators arranged corresponding to a plurality of pixels which in turn correspond to a plurality of dots, the drive section controlling a displacement of the plurality of actuators in contacting and separating directions with respect to the optical wave guide plate, the displacement corresponding to attributes of an input image signal, thereby causing an image to be displayed on the optical wave guide plate corresponding to the image signal by controlling a leakage light from specified parts of the optical wave guide plate; each of the actuators including a shape retaining portion consisting of at least first and second layers, wherein the first and second layers are partially separated by a row electrode, and wherein the shape retaining portion is bounded on an upper and lower side by a column electrode; a first drive circuit which applies an offset potential to all of the actuators; a second drive circuit which outputs a data signal for each dot, the data signal being based on the image signal, the data signal comprising one of a light emitting signal and a light extinguishing signal; and a signal processing circuit which controls the first and second drive circuits wherein one dot is configured by one or more actuators and one pixel is configured by one or more dots.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026]

Fig. 1 is an oblique view of a schematic diagram of a display to which the display driving device of an embodiment of the present invention is applied.

Fig. 2 is a cross-sectional drawing of the configuration of a display element.

Fig. 3 is an explanatory diagram showing the pixel configuration of a display element.

Fig. 4 is a cross sectional drawing showing the first example of the configuration of the actuator and pixel structural

unit.

Fig. 5 is a diagram showing one example of the flat configuration of a pair of electrodes formed in the actuator.

Fig. 6A is an explanatory diagram showing an example of comb teeth of a pair of electrodes arranged following a major axis of shape retaining layer.

Fig. 6B is an explanatory diagram showing another example of comb teeth of a pair of electrodes arranged following a major axis of shape retaining layer.

Fig. 7A is an explanatory diagram showing an example of comb teeth of a pair of electrodes arranged following a minor axis of shape retaining layer.

Fig. 7B is an explanatory diagram showing another example of comb teeth of a pair of electrodes arranged following a minor axis of shape retaining layer.

Fig. 8 is a cross-sectional drawing showing another configuration of a display element.

Fig. 9 is a cross-sectional drawing showing a second example of the configuration of the actuator and pixel structural unit.

Fig. 10 is a cross-sectional drawing showing a third example of the configuration of the actuator and pixel structural unit.

Fig. 11 is a cross-sectional drawing showing a fourth example of the configuration of the actuator and pixel structural unit.

Fig. 12 is an explanatory diagram showing the configuration when respective bars are formed in the four directions of the pixel structural unit.

Fig. 13 is an explanatory diagram showing another configuration of bars.

Fig. 14 is a table showing the relationship between the offset electric potential (bias electrical potential) output from a low electrode drive circuit and the electrical potential of an ON signal output from a column electrode drive circuit and low electrode and the voltage applied between column poles.

Fig. 15 is a circuit diagram showing the configuration of the drive device of the first and second embodiments.

Fig. 16 is a block diagram showing the configuration of driver IC in column electrode drive circuits of the drive device of the first embodiment.

Fig. 17 is a diagram showing examples in which one frame in particular is divided up into numerous sub-fields in order to explain gradation control in the drive device of the first embodiment.

Fig. 18 is a block diagram showing signal processing circuits in the drive device of the first embodiment.

Fig. 19 is a table showing another example of the relationship between the offset electric potential (bias electrical potential) output from a low electrode drive circuit and the electrical potential of an ON signal output from a column electrode drive circuit and low electrode and the voltage applied between column poles.

Fig. 20 is a table showing still another example of the relationship between the offset electric potential (bias electrical potential) output from a low electrode drive circuit and the electrical potential of an ON signal output from a column electrode drive circuit and low electrode and the voltage applied between column poles.

Fig. 21 is a diagram showing examples in which one frame in particular is divided up into numerous linear sub-fields in order to explain gradation control in the drive device of the second embodiment.

Fig. 22A is an explanatory diagram showing the bit arrangement when the gradation level is sixty-two in the dot data created by the drive device of the second embodiment.

Fig. 22B is an explanatory diagram showing the bit arrangement when the gradation level is eight in the dot data created by the drive device of the second embodiment.

Fig. 23 is a block diagram showing the signal processing circuits in drive devices of the second and fourth embodiments.

Fig. 24 is a block diagram showing the configuration of the driver IC used by the driving device of the second embodiment.

Fig. 25 is a block diagram showing the configuration of the data transfer portion used by the driving device of the second embodiment.

Fig. 26 is an explanatory diagram showing the data partition of the first data output circuit.

Fig. 27 is an explanatory diagram showing the data transfer format to the second output circuit from the first output circuit.

Fig. 28 is a circuit diagram showing the configuration of the driving devices of the third and fourth embodiments.

Fig. 29 is a drawing showing, in particular, an example of one frame divided into two fields and a further single field divided into numerous subfields for the purpose of explaining gradation control in the driving device of the third embodiment.

Fig. 30 is a block diagram showing a signal processing circuit in the driving device of the third embodiment.

Fig. 31 is a table showing the relationship between the electrical potentials of a selected and a non-selected signal output from a low electrode drive circuit and the electrical potential of an ON signal output from a column electrode drive circuit and low electrode and the voltage applied to between column poles.

Fig. 32 is a table showing another example of the relationship between the electrical potentials of a selected and a non-selected signal output from a low electrode drive circuit and the electrical potential of an ON signal output from a column electrode drive circuit and low electrode and the voltage applied between column poles.

Fig. 33 is a table showing still another example of the relationship between the electrical potentials of a selected and a non-selected signal output from a low electrode drive circuit and the electrical potential of an ON signal output from a column electrode drive circuit and low electrode and the voltage applied between column poles.

Fig. 34 is a drawing showing an example of one frame divided into two fields and further one field equally divided into numerous linear subfields for the purpose of explaining gradation control in the driving device of the fourth embodiment.

Fig. 35 is a block diagram showing a signal processing circuit of the driving device of the fourth embodiment.

Fig. 36 is an explanatory diagram showing the pixel configuration of a display element that is applied by the driving device of the fifth embodiment.

Fig. 37 is a drawing showing an example of one frame divided into two fields and further one field divided into numerous subfields for the purpose of explaining gradation control in the driving device of the fifth embodiment.

Fig. 38 is a circuit diagram showing the configuration of the driving device of the fifth and sixth embodiments.

Fig. 39 is a block diagram showing a signal processing circuit in the driving device of the fifth embodiment.

Fig. 40 is a drawing showing an example of one frame divided into three fields and further one field equally divided into numerous linear subfields for the purpose of explaining gradation control in the driving device of the sixth embodiment.

Fig. 41 is a block diagram showing a signal processing circuit in the driving device of the sixth embodiment.

Fig. 42A is a cross-sectional drawing showing the state of light being emitted in an example of a display element which uses static electricity.

Fig. 42B is a cross section of the state in the example of Fig. 42A when that light is extinguished.

Fig. 43A is a cross-sectional drawing showing the state of light being emitted in another example of a display element which uses static electricity.

Fig. 43B is a cross section of the state in the example of Fig. 43A when that light is extinguished.

Fig. 44 is a cross-sectional drawing showing another configuration of an actuator.

Fig. 45 is a block diagram for explaining a brightness correction mechanism.

Fig. 46 is a graph showing an example of brightness distribution for each dot.

Fig. 47 is a graph showing another example of brightness distribution for each dot.

Fig. 48 is a block diagram for explaining a liner correction mechanism.

Fig. 49A is drawing showing the brightness properties of a given dot.

Fig. 49B is a graph showing a weighting factor for making brightness properties linear.

Fig. 49C is a graph showing brightness distribution after making brightness properties linear.

Fig. 50A is a graph showing brightness properties of a television signal that has been gamma corrected.

Fig. 50B is a graph showing a weighting factor for deleting gamma correction.

Fig. 50C is a graph showing brightness distribution after making brightness properties linear.

Fig. 51 is a block diagram for explaining a light adjustment control mechanism.

Fig. 52A is a timing chart showing an example of power source switch timing.

Fig. 52B is a timing chart showing an example of a combination of linear subfields selected corresponding to gradation level.

Fig. 53A is a timing chart showing another example of power source switch timing.

Fig. 53B is a timing chart showing another example of a combination of linear subfields selected corresponding to gradation level.

Fig. 54A shows a signal applied to a column electrode in normal driving.

Fig. 54B shows a signal applied to a row electrode.

Fig. 54C shows a voltage applied to a dot.

Fig. 55A shows the applied voltage wave form in normal operation.

Fig. 55B shows the light intensity distribution of Fig. 55A.

Fig. 56A shows a signal applied to a column electrode when a preliminary interval is provided.

Fig. 56B shows a signal applied to a row electrode.

Fig. 56C shows voltage applied to a dot.

Fig. 57A shows the applied voltage wave form when a preliminary interval is provided.

Fig. 57B shows the light intensity distribution of Fig. 57A.

Fig. 58 shows an example of circuits used in row electrode drive circuits.

Fig. 59 is a block diagram showing the first specific example of a form of use.

Fig. 60 is a block diagram showing the second specific example of a form of use.

Fig. 61 is a block diagram showing the third specific example of a form of use.

Fig. 62 is a block diagram showing a first variation of the third specific example of a form of use.
Fig. 63 is a block diagram showing a second variation of the third specific example of a form of use.
Fig. 64 is a block diagram showing the fourth specific example of a form of use.
Fig. 65 is a block diagram showing the fifth specific example of a form of use.
Fig. 66 is a schematic diagram showing the display device of a prior art example.
Fig. 67 is a block diagram showing the peripheral circuits of a prior art display device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0027] The preferred embodiments of the display driving device and method of driving a display of the present invention are explained with reference to Figs. 1 through 65. However, we explain the configuration of a display to which the driving device of the preferred embodiment is to be applied with reference to Figs. 1 through 13.

[0028] Referring to Fig. 1, a display 10 with numerous display elements 14 is arranged in rows on the back of light guide plates 12 having a display area. For example, with VGA standards, forty display elements 14 are arranged in a horizontal direction and thirty display elements 14 are arranged in a vertical direction on the back of light guide plate 12 so that 640 pixels (1920 dots) are lined up in the horizontal direction and 480 pixels (480 dots) are lined up in the vertical direction. Light guide plate 12 uses a uniform material of glass plate or acrylic plate etc. which transmits visible light. Each display element 14 is such that it supplies signals with others by being connected by wire bonding, soldering, end connectors, back connectors etc.

[0029] Referring to Fig. 2, each display element 14 is configured to have an optical wave guide plate 20 which introduces light 18 from a light source 16. Each display element 14 also has a drive section 24, provided opposite to the back of optical wave guide plate 20, which has numerous actuators 22 arranged in the shape of a matrix or zigzag shape corresponding to pixels. The optical wave guide plate 20 of each display element 14 and light guide plate 12 preferably have similar refraction indexes. When light guide plate 12 and optical wave guide plate 20 are mounted together, a transparent bonding agent may be used. This bonding agent, like the light guide plate 12 and optical wave guide plate 20, should preferably be uniform in visible light ranges and have a high transmittance rate. Specifying something with a refraction index close to that of light guide plate 12 and optical wave guide plate 20 is preferable in terms of guaranteeing brightness of the screen.

[0030] Pixel structural units 30 are laminated on each actuator 22 in each display element 14. Pixel structural units 30 increase the contact area with optical wave guide plate 20 and function to make an area which corresponds to the pixel. Drive portion 24 has an actuator substrate 32 composed of ceramic material, with actuators 22 placed in positions corresponding to each pixel 28 of actuator substrate 32. The main surface of actuator substrate 32 is disposed in a continuous face (flush face) opposite to the back face of optical wave guide plate 20. Hollow places 34 for forming respective vibrators are provided in locations corresponding to each pixel 28 in the interior of actuator substrate 32. Each of these hollow places 34 is linked to the exterior via a through hole 36 which has a small bore and is provided on the other end of actuator substrate 32.

[0031] The portion where hollow place 34 is formed in actuator substrate 32 is thin with the remainder of actuator substrate 32 being thick. The thin portion has a structure which easily vibrates with external stress to function with vibrator 38 while the thicker portions function as securing portions 40 which support vibrators 38. In other words, actuator substrate 32 is a laminated unit of a substrate layer 32A, the lowest layer, an intermediate spacer layer 32B, and a thin plate layer 32C, the top most layer. Actuator substrate 32 can be thought of as a unitary structure with hollow places 34 in spacer layer 32B formed in positions corresponding to actuators 22.

[0032] Referring to Fig. 3, a pixel 28 has three horizontal dots 26R, 26G, and 26B with each dot 26 having two actuators 22 lined up in a vertical direction. Display element 14 (Fig. 1) consists of sixteen lines of pixels 28(48 dots) in a horizontal direction and 16 lines of pixels (16 dots) in a vertical direction.

[0033] Referring to Fig. 4, actuator 22 includes a shape retaining layer 46 composed of a piezoelectric/ electrostrictive layer or an anti-ferroelectric layer etc. formed directly on vibrator 38. A pair of electrodes 48 (row electrode 48a and column electrode 48b) are formed on the upper and lower faces of shape retaining layer 46. The pair of electrodes 48 optionally have a structure formed above and below shape retaining layer 46 or alternately on only one side of it, or electrodes 48 may be formed only in the upper part of shape retaining layer 46. A gap forming layer 44 is provided between bar 42 and optical wave guide plate 20. Pixel structural unit 30 can be configured as a laminated unit of white diffuse 50 and color filter 52 with a transparent layer 54 acting as the displacement transfer portion (reference numeral 420 in Fig. 44) formed on actuator 22.

[0034] When forming the pair of electrodes 48 only in the upper part of shape retaining layer 46, the planar configuration of the pair of electrodes 48 may have a configuration in which numerous comb teeth are juxtaposed complementarily as shown in Fig. 5 or alternately one may adopt a spiral or branched configuration. When the planar configuration of shape retaining layer 46 is an oval configuration and a pair of electrodes 48 are configured as comb teeth, then the comb teeth of the pair of electrodes 48 may be arranged along the major axis of shape retaining layer

46 as shown in Figs. 6A and 6B or the comb teeth of the pair of electrodes 48 may be arranged along the minor axis of shape retaining layer 46 as shown in Figs. 7A and 7B.

[0035] As shown in Figs. 6A and 7A, the comb teeth configured portion of the pair of electrodes 48 may be included within the planar configuration of shape retaining layer 46 or as shown in Figs. 6B and 7B, the comb teeth configured portion of the pair of electrodes 48 may protrude from the planar configuration of shape retaining layer 46. The forms shown in Figs. 6B and 7B are advantageous in the bending and displacement of actuator 22.

[0036] If the pair of electrodes 48 is arranged so that the upper face of shape retaining layer 46 forms row electrode 48a and the lower face of shape retaining layer 46 forms column electrode 48b, as shown in Fig. 4, it is possible to displace actuator 22 bending it in one direction convex to hollow place 34. Alternately, as shown in Fig. 8, it is possible to displace actuator 22 in another direction so that it will be convex to optical wave guide plate 20. The embodiment shown in Fig. 8 is an instance when gap forming layer 44 (see Fig. 4) is not formed.

[0037] As shown in Figure 9, a light reflecting layer 56 may be placed as a layer below white diffusing layer 50. In this case, it is preferable to form insulation layer 58 between light reflecting layer 56 and actuator 22.

[0038] As shown in Fig. 10, pixel structural unit 30 may also be configured with a laminated unit of color diffuser 60, also functioning as a displacement transfer portion, and transparent layer 54. In this case, light reflecting layer 56 and insulation layer 58 may be interposed between actuator 22 and color diffuser 60.

[0039] In addition, display element 14, as Figs. 2, 4, and 8 show, may be configured to have a bar 42 formed in a portion other than in pixel structural unit 30 between optical wave guide plate 20 and actuator substrate 32. In the embodiment shown in Fig. 8, optical wave guide plate 20 is secured to the top face of bar 42. The material of bar 42 should preferably not be misshapen by heat or pressure.

[0040] Bar 42 may be formed in the four directions of pixel structural unit 30, for example. Here the four directions refer to a position corresponding to each corner if pixel structural unit 30 is, for example, a plane nearly rectangular or oval. Each bar 42 has a shape common with adjacent pixel structural units 30.

[0041] Bar 42 may be configured as shown in Fig. 13 to have a window portion 42 a which encloses at least one pixel structural unit 30. For a representative example of configuration, for example, bar 42 itself is formed as a plate and in addition, forms window portion (opening) 42 a which has a configuration similar to the external configuration of pixel structural unit 30 in a position corresponding to pixel structural unit 30. Thus, all of the sides of pixel structural unit 30 will be enclosed by bar 42 and the bond with actuator substrate 32 and optical wave guide plate 20 will be further strengthened.

[0042] Here we explain each of the parts configuring display element 14, and in particular, the selection of materials etc. of each of the constituent parts. First, the light incident on optical wave guide plate 20 may be either ultra-violet, visible, or infra-red. For light source 16, incandescent lamps, deuterium discharge lamps, fluorescent lamps, mercury lamps, metal halide lamps, halogen lamps, xenon lamps, tritium lamps light emitting diodes, lasers, plasma light sources, hot cathode tubes, and cold cathode tubes etc. are used.

[0043] Vibrator 38 is preferably of high heat resistant material. The reason for this is that when making actuator 22 into a structure which directly supports vibrator 38 by virtue of securing portion 40, and materials inferior in heat resistance such as organic glues are not used, vibrator 38 should preferably be made of high heat resistant material so that vibrator 38 does not change qualitatively while shape retaining layer 46 is forming. Vibrator 38 should preferably be an electrically insulating material in order to separate the circuits to row electrode 48a and column electrode 48b (for example data circuits) in the pair of electrodes formed on actuator substrate 22. Thus, vibrator 38 may be a highly heat resistant metal or a hollow etc. material whose metal surface is covered with a ceramic material such as glass but ceramics are most suitable.

[0044] Stabilized zirconium oxide, aluminum oxide, magnesium oxide, titanium oxide, spinel, mullite, aluminum nitride, silicon nitride, glass, or compounds of these may used as the ceramic material comprising vibrator 38. Stabilized zirconium oxide is particularly preferable for various reasons: it has exceptional mechanical strength even though vibrator 38 may be thin, it is very tough, and there is very little chemical reactivity with shape retaining layer 46 and the pair of electrodes 48. Stabilized zirconium oxide includes stabilized zirconium oxide as well as partially stabilized zirconium oxide. Since the ceramic will have a cubic etc. crystalline structure with stabilized zirconium oxide, phase changes will not occur.

[0045] On the other hand, zirconium oxide phase changes to monoclinic or tetragonal at around 1000 °C and at the time of this phase change cracks may occur. Stabilized zirconium oxide contains 1-30 mol% of stabilizing agents of such things as calcium oxide, magnesium oxide, yttrium oxide, scandium oxide, ytterbium oxide, cerium oxide or oxides of rare earth metals. To enhance the mechanical strength of vibrator 38, the stabilizing agent should include yttrium oxide. For this it should contain 1.5-6 mol% yttrium oxide and more preferably should contain 2-4 mol%. Still more preferably, it should contain 0.1 -5 mol% of aluminum oxide.

[0046] Crystal phase may be a compound phase of cubic plus monoclinic, a compound phase of tetragonal plus monoclinic or a compound of cubic plus tetragonal plus monoclinic etc. but those in which the principal crystal is either tetragonal or tetragonal plus cubic are preferable from the standpoint of strength, toughness and durability.